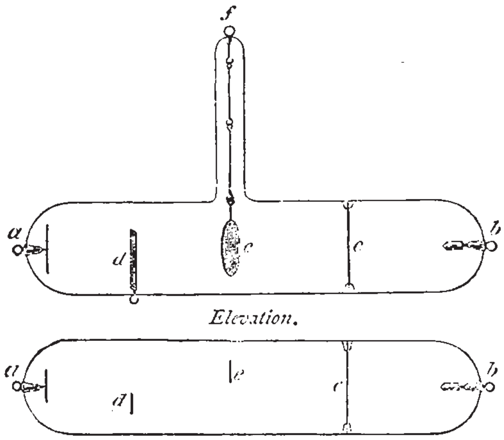
vacuum is so high that the spark has difficulty in passing, the penumbra (which becomes visible on insulating the idle pole) is much wider than before, and apparently eight or ten times as wide as it was at the lowest exhaustion at which observations were taken.

If the object whose shadow is cast on the screen is a non-conductor (such as a piece of glass rod), its shadow remains constant at all exhaustions, no penumbra being visible, as it cannot be uninsulated.

Prof. Stokes, whose suggestions throughout the course of this research have been most valuable, considered that much information might be gained by experimenting with an apparatus constructed in the following manner: the two poles of the tube (Fig. 9) are at *a* and *b*. At *c* is a



Elevation.

Plan.

FIG. 9.

FIG. 9A.

FIG. 9B.

FIG. 9C.

fluorescent screen; *d* is a fixed bar of aluminium, and *e* is another aluminium bar hanging from a platinum pole *f*, by a metal chain. The bar and pendulum are on opposite sides of the horizontal axis of the tube, as shown in the plan, so that when properly exhausted and the pole *a* made negative, the shadows of bar and pendulum shall fall side by side on the screen, as shown in Fig. 9A. On swinging the pendulum, the shadow alternately overlaps and recedes from the shadow of the bar (Figs. 9B and 9C).

This apparatus was tried many times with an induction coil, and also with a Holtz machine; but the results were not sufficiently definite to render it safe to draw any inference from them. By the kindness of Mr. De La Rue I have lately had the opportunity of experimenting with his large chloride of silver battery, and the results now come out with great sharpness and with none of the flickering and indecision met with when working with an induction-coil.

The tube was so adjusted that the pendulum hung free, and a narrow line of molecular discharge passed between the edges of the bar and the pendulum, forming a line of light between the two shadows on the screen (Fig. 9A). When the pendulum was set swinging, and the idle pole *f* connected with it was kept insulated, the regular appearance of the moving and fixed shadows was very slightly interfered with. That is to say, the shadows followed the successive positions between those shown in Figs. 9B and 9C almost as if they had been cast by a luminous point in place of the negative pole. As the shadow of the swinging pendulum came very near that of the bar, the latter shadow seemed to shrink away, showing that the pendulum itself exerted slight repulsion on the molecules which passed close to its edge.

The pendulum was again set stationary, as shown on the plan (Fig 10), the line of light separating the two

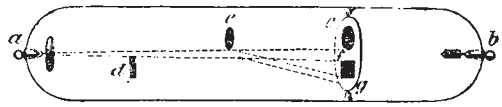


FIG. 10.

being at *f*, so that the appearance on the screen was as shown at Fig. 9A. The pendulum pole was then connected with earth, and instantly the line of light which separated the poles moved from *f* to *g* through an angle, measured from *e*, of about 30°, the shadow widening out and getting indistinct at the same time.

When the pole *a* was negative and *b* positive, the bar *d* and pendulum *e* were each found to be positively electrified. The outside of the glass tube, both near the negative pole and near the positive pole, was also positively electrified.

The above experiments were tried with 6300 cells, a resistance equal to 800,000 ohms being interposed. The current through the tube was 0·00383 weber. These measurements were taken by Mr. De La Rue, to whom I am greatly indebted for permission to experiment with his magnificent battery, and who himself kindly assisted me in making the arrangements. WILLIAM CROOKES

(*To be continued.*)

ROCK-WEATHERING, AS ILLUSTRATED IN CHURCHYARDS[1]

COMPARATIVELY little has yet been done in the way of precise measurement of the rate at which the exposed surfaces of different kinds of rock are removed in the processes of weathering. A few years ago some experiments were instituted by Prof. Pfaff of Erlangen to obtain more definite information on this subject. He exposed to ordinary atmospheric influences carefully measured and weighed pieces of Solenhofen limestone, syenite, granite (both rough and polished), and bone. At the end of three years he found that the loss from the limestone was equivalent to the removal of a uniform layer 0·04 mm in thickness from its general surface. The stone had become quite dull and earthy, while on parts of its surface fine cracks and incipient exfoliation had appeared.[2] The time during which the observations were continued is however too brief to allow any general deductions to be drawn from them as to the real average rate of disintegration. Prof. Pfaff relates that during the period a severe hailstorm broke one of the plates of stone. An exceptionally powerful cause of this nature might make the loss during a short interval considerably greater than the true average of a longer period.

It occurred to me recently that data of at least a provisional value might be obtained from an examination of tombstones freely exposed to the air in graveyards in cases where their dates remained still legible or might be otherwise ascertained. I have accordingly paid attention to the older burial-grounds in Edinburgh, and have gathered together some facts which have perhaps sufficient interest and novelty to be communicated to the Society.

At the outset it is of course obvious that in seeking for

[1] A Paper read to the Royal Society of Edinburgh, on April 19, by Prof. Geikie, F.R.S.

[2] "Allgemeine Geologie als exacte Wissenschaft," p. 317.

data bearing on the general question of rock-weathering we must admit the kind and amount of such weathering visible in a town to be in some measure different from what is normal in nature. So far as the disintegration of rock-surfaces is effected by mineral acids, for example, there must be a good deal more of such chemical change where sulphuric acid is copiously evolved into the atmosphere from thousands of chimneys than in the pure air of country districts. In these respects we may regard the disintegration in towns as an exaggeration of the normal rate. Still the difference between town and country may be less than might be supposed. Surfaces of stone are apt to get begrimed with dust and smoke, and the crust of organic and inorganic matter deposited upon them may in no small measure protect them from the greater chemical activity of the more acid town rain. In regard to the effect of daily or seasonal changes of temperature, on the other hand, any difference between town and country may not impossibly be on the side of the town. Owing probably to the influence of smoke in retarding radiation, thermometers placed in open spaces in town commonly mark an extreme nocturnal temperature not quite so low as those similarly placed in the suburbs, while they show a maximum day temperature not quite so high.

The illustrations of rock-weathering presented by city graveyards are necessarily limited to the few kinds of rock employed for monumental purposes. In this district the materials used are of three kinds: 1st, Calcareous, including marbles and limestones; 2nd, Sandstones and flagstones; 3rd, Granites.

I. CALCAREOUS.—With extremely rare exceptions, the calcareous tombstones in our graveyards are constructed of ordinary white saccharoid Italian marble. I have also observed a pink Italian shell-marble and a finely fossiliferous limestone containing fragments of shells, foraminifera, &c.

In a few cases the white marble has been employed by itself as a monolith in the shape of an obelisk, urn, or other device; but most commonly it occurs in slabs which have been tightly fixed in a framework of sandstone. These slabs, from less than one to fully two inches thick, are generally placed vertically; in one or two examples they have been inserted in large horizontal sandstone slabs or "through-stanes." The form into which it has been cut and the position in which it has been erected have had considerable influence on the weathering of the stone.

A specimen of the common white marble employed for monumental purposes was obtained from one of the marble works of the city, and examined microscopically. It presented the well-known granular character of true saccharoid marble, consisting of rounded granules of clear transparent calcite, averaging about $\frac{1}{100}$ inch in diameter. Each granule has its own system of twin lamellations, and not unfrequently gives interference colours. The fundamental rhombohedral cleavage is everywhere well developed. Not a trace exists of any amorphous granular matrix or base holding the crystalline grains together. These seem moulded into each other, but have evidently no extraordinary cohesion. A small fragment placed in dilute acid was entirely dissolved. There can be no doubt that this marble must be very nearly pure carbonate of lime.

The process of weathering in the case of this white marble presents three phases, sometimes to be observed on the same slab, viz., Superficial Solution, Internal Disintegration, and Curvature with Fracture.

(1) *Superficial solution* is effected by the carbonic acid and partly by the sulphuric acid of town rain. When the marble is first erected it possesses a well-polished surface capable of affording a distinct reflection of objects placed in front of it. Exposure for not more than a year or two to our prevalent westerly rains suffices to remove this polish, and to give the surface a rough granular character. The granules which have been cut across or bruised in the cutting and polishing process are first attacked, and removed in solution or drop out of the stone. An obelisk in Greyfriars churchyard erected in memory of a lady who died in 1864 has so rough and granular a surface that it might readily be taken for a sandstone. So loosely are the grains held together that a slight motion of the finger will rub them off. In the course of solution and removal the internal structure of the marble begins to reveal itself. Its harder nests and veinings of calcite and other minerals project above the surrounding surface, and may be traced as prominent ribs and excrescences running across the faint or illegible inscriptions. On the other hand some portions of the marble are more rapidly removed than others. Irregular channels, dependent partly on the direction given to trickling rain by the form of the monumental carving, but chiefly on original differences in the internal structure of the stone, are gradually hollowed out. In this way the former artificial surface of the marble disappears, and is changed into one that rather recalls the bare, bleached rocks of some mountain side.

The rate at which this transformation takes place seems to depend primarily on the extent to which the marble is exposed to rain Slabs which have been placed facing to north-east, and with a sufficiently projecting architrave to keep off much of the rainfall, retain their inscriptions legible for a century or longer. But even in these cases the progress of internal disintegration is distinctly visible. Where the marble has been less screened from rain the rapidity of waste has been sometimes very marked. A good illustration is supplied by the tablet of G—— G——, on the south side of Greyfriars Churchyard, who died in 1785.[1] This monument had become so far decayed as to require restoration in 1803. It is now, and has been for some years, for the most part utterly illegible. The marble has been dissolved away over the centre of the slab to a depth of about a quarter of an inch. Yet this monument is by no means in an exposed situation. It faces eastward in a rather sheltered corner, where, however, the wind eddies in such a way as to throw the rain against the part of the stone which has been most corroded.

In the majority of cases superficial solution has been retarded by the formation of a peculiar grey or begrimed crust, to be immediately described. The marble employed here for monumental slabs appears to be peculiarly liable to the development of this crust. Another kind of white marble, sometimes employed for sculptured ornaments on tombstones, dissolves without crust. It is snowy white, and more translucent than the ordinary marble. So far as the few weathered specimens I have seen enable me to judge, it appears to be either Carrara marble or one of the strongly saccharoid, somewhat translucent varieties employed instead of it. This stone, however, though it forms no crust, suffers marked superficial solution. But it escapes the internal disintegration which, so far as I have observed, is always an accompaniment of the crust. But the few examples of it I have met with hardly suffice for any comparison between the varieties.

(2) *Internal Disintegration.*—Many of the marble monuments in our older churchyards are covered with a dirty crust, beneath which the stone is found on examination to be merely a loose crumbling sand. This crust seems to form chiefly where superficial solution is feeble. It may be observed to crack into a polygonal network, the individual polygons occasionally curling up so as to reveal the yellowish white crumbling material underneath. It also rises in blisters, which, when they break, expose the interior to rapid disintegration.

So long as this begrimed film lasts unbroken the smooth face of the marble slab remains with apparently little modification. The inscription may be perfectly

[1] For obvious reasons I withhold the names carved on the tombstones referred to in this communication.

legible; the moment the crust is broken up, however, the decay of the stone is rapid. For we then see that the cohesion of the individual crystalline granules of the marble has already been destroyed, and that the merest touch causes them to crumble into a loose sand.

It appears therefore that two changes take place in upright marble slabs freely exposed to rain in our burial-grounds—a superficial, more or less firm crust is formed, and the cohesion of the particles beneath is destroyed.

The crust varies in colour from a dirty grey to a deep brown black, and in thickness from that of writing-paper up to sometimes at least a millimetre. One of the most characteristic examples of it was obtained from an utterly decayed tomb (erected in the year 1792), on the east side of Canongate Churchyard. No one would suppose that the pieces of flat dark stone lying there on the sandstone plinth were once portions of white marble. Yet a mere touch suffices to break the black crust, and the stone at once crumbles to powder. Nevertheless the two opposite faces of the original polished slab have been preserved, and I even found the sharply-chiselled socket-hole of one of the retaining nails. The specimen was carefully removed and soaked in a solution of gum, so as to preserve it from disintegration. On submitting the crust of the marble to microscopic investigation, I found it to consist of particles of coal, grains of quartz sand, angular pieces of broken glass, fragments of red brick or tile, and organic fibres. This miscellaneous collection of town dust was held together by some amorphous cement which was not dissolved by hydrochloric acid. At my request my friend Mr. B. N. Peach tested it with soda on charcoal, and at once obtained a strong sulphur reaction. There can be little doubt that it is mainly sulphate of lime. The crust which forms upon our marble tombstones is thus a product of the reaction of the sulphuric acid of the town rain upon the carbonate of lime. A pellicle of amorphous gypsum is deposited upon the marble and incloses the particles of dust which give the characteristic sooty aspect to the stone. This pellicle, of course, when once formed, is comparatively little affected by the chemical activity of rain-water. Hence the conservation of the even surface of the marble. It is liable, however, to be cracked by an internal expansion of the stone to which I shall immediately refer, and also to rise in small blisters, and as I have said, its rupture leads at once to the rapid disintegration of the monument.

The cause of this disintegration is the next point for consideration. Chemical examination revealed the presence of a slight amount of sulphate in the heart of the crumbling marble; but the quantity appeared to me to be too small seriously to affect the cohesion of the stone. I submitted to microscopic examination a portion of a crumbling urn of white marble in Canongate Churchyard. The tomb bears a perfectly fresh date of "1792" cut in sandstone over the top; but the marble portions are crumbling into sand, though the structure faces the east, and is protected from vertical rain by arching mason-work. A small portion of the marble retaining its crust was boiled in Canada balsam, and was then sliced at right angles to its original polished surface. By this means a section of the crumbled marble was obtained which could be compared with one of the perfectly fresh stone. From the dark outer amorphous crust with the carbonaceous and other miscellaneous particles fine rifts could be seen passing down between the separated calcite granules, which in many cases were quite isolated. The black crust descends into these rifts, and likewise passes along the cleavage planes of the granules. Towards the outer surface of the stone immediately beneath the crust the fissures are chiefly filled with a yellowish, structureless substance, which gave a feeble glimmering reaction with polarised light, and inclosed minute amorphous aggregates like portions of the crust. It probably consists chiefly of sulphate of lime. But the most remarkable feature in the slide was the way in which the calcite granules had been corroded. Seen with reflected light, they resembled those surfaces of spar which have been placed in weak hydrochloric acid to lay bare inclosed crystals and zeolites. The solution had taken place partly along the outer surfaces, so as to produce the fine passage or rifts, and partly along the cleavage. Deep cavities, defined by intersecting cleavage planes, appeared to descend into the heart of some of the granules. In no case did I observe any white pellicle such as might indicate a redeposit of lime from the dissolved carbonate. Except for the veining of probable sulphate just referred to, the lime when once dissolved had apparently been wholly removed in solution. There was further to be observed a certain dirtiness, so to speak, which at the first glance distinguished the section of crumbled marble from the fresh stone. This was due partly to corrosion, but chiefly to the introduction of particles of soot and dust, which could be traced among the interstices and cleavage lamellæ of the crystalline granules, for some distance back from the crust.

It may be inferred, therefore, that the disintegration of the marble is mainly due to the action of carbonic acid in the permeating rain-water, whereby the component crystalline granules of the stone are partially dissolved and their mutual adhesion is destroyed. This process goes on in all exposures, and with every variety in the thickness of the outer crust. It is distinctly traceable in tombstones that have not been erected for more than twenty years. In those which have been standing for a century it is, save in exceptionally sheltered positions, so far advanced that a very slight pressure suffices to crumble the stone into powder. But with this internal disintegration we have to take into consideration the third phase of weathering to which I have alluded. In the upright marble slabs it is the union of the two kinds of decay which leads to so rapid an effacement of the monuments.

3. *Curvature and Fracture.*—This most remarkable phase of rock-weathering is only to be observed in the slabs of marble which have been firmly inserted into a solid framework of sandstone and placed in an erect or horizontal position. It consists in the bulging out of the marble, accompanied with a series of fractures. The change cannot be explained as mere sagging by gravitation, for it usually appears as a swelling up of the centre of the slab, which continues until the large, blister-like expansion is disrupted. Nor is it by any means exceptional; it occurs as a rule on all the older upright marble tablets, and is only found to be wanting in those cases where the marble has evidently not been fitted tightly into its sandstone frame. Wherever there has been little or no room for expansion, protuberance of the marble may be observed. Successive stages may be seen, from the first gentle uprise to an unsightly swelling of the whole stone. This change is accompanied by fracture of the marble. The rents in some cases proceed from the margin inwards, more particularly from the upper and under edges of the stone, pointing unmistakably to an increase in volume as the cause of fracture. In other cases the rents appear in the central part of the swelling, where the tension from curvature has been greatest.

Some exceedingly interesting examples of this singular process of weathering are to be seen in Greyfriars Churchyard. On the south wall, in the inclosure of a well-known county family, there is an oblong upright marble slab measuring 30¼ inches in height by 22⅝ inches in breadth, and ⅞ inch in thickness, facing west. The last inscription on it bears the date 1838, at which time it was no doubt still smooth and upright. Since then, however, it has escaped from its fastenings on either side, though still held firmly at the top and bottom. It consequently projects from the wall like a well-filled sail. The axis of curvature is of course parallel to the upper and lower margins, and the

amount of curvature from the original vertical line is fully $2\frac{1}{2}$ inches, so that the hand and arm can be inserted between the curved marble and the perfectly vertical and undisturbed wall to which it was fixed. At the lower end of this slab a minor curvature, to the extent of $\frac{1}{8}$ inch, is observable coincident with the longer axes of the stone. In both cases the direction of the bending has been determined by the position of the inclosing solid frame of sandstone which resisted the internal expansion of the marble. Freed from its fastenings at either side, the stone has assumed a simple wave-like curve. But the tension has become so great that a series of rents has appeared along the crest of the fold. One of these has a breadth of $\frac{1}{10}$ inch at its opening.[1] Not only has the slab been ruptured, but its crust has likewise yielded to the strain, and has broken up into a network of cracks, and some of the isolated portions are beginning to curl up at the edges, exposing the crumbling, decayed marble below. I should add that such has been the expansive force of the marble that the part of the sandstone block in the upper part of the frame exposed to the direct pressure has begun to exfoliate, though elsewhere the stone is quite sound.

More advanced stages of curvature and fracture may be noticed on many other tombstones in the same burying-place. One of the most conspicuous of these has a peculiar interest from the fact that it occurs on the tablet erected to the memory of one of the most illustrious dead whose dust lies within the precincts of the Greyfriars—the great Joseph Black. He died in 1799. In the centre of the sumptuous tomb raised over his grave is inserted a large upright slab of white marble, which, facing south, is protected from the weather partly by heavy over-hanging masonry, and partly by a high stone wall immediately to the west. On this slab a Latin inscription records with pious reverence the genius and achievements of the discoverer of carbonic acid and latent heat, and adds that his friends wished to mark his resting-place by the marble whilst it should last. Less than eighty years, however, have sufficed to render the inscription already partly illegible. The stone, still firmly held all round its margin, has bulged out considerably in the centre, and on the blister-like expansion has been rent by numerous cracks which run on the whole in the direction of the length of the stone.

A further stage of decay is exhibited by a remarkable tomb on the west wall of the Greyfriars Churchyard. The marble slab, bearing a now almost wholly effaced inscription, on which the date 1779 can be seen, is still held tightly within its inclosing frame of sandstone slabs, which are firmly built into the wall. But it has swollen out into a ghastly protuberance in the centre, and is moreover seamed with rents which strike inwards from the margins. In this and in some other examples the marble seems to have undergone most change on the top of the swelling, partly from the system of fine fissures by which it is broken up, and partly from more direct and effective access of rain. Eventually the cohesion of the stone at that part is destroyed, and the crumbling marble falls out, leaving a hole in the middle of the slab. When this takes place disintegration proceeds rapidly. Three years ago I sketched a tomb in this stage on the east wall of Canongate Churchyard. In a recent visit to the place I found that the whole of the marble had since fallen out.

The first cause that naturally suggests itself in explanation of this remarkable change in the structure of a substance usually regarded as so inelastic is the action of frost. White statuary marble is naturally porous. It is rendered still more so by that internal solution which I have described. The marble tombstones in our graveyards are therefore capable of imbibing a relatively large amount of moisture. When this interstitial water is frozen its expansive force as it passes into the solid state must increase the isolation of the granules and augment the dimensions of a marble block. I am inclined to believe that this must be the principal cause of the change. Whatever may be the nature of the process, it is evidently one which acts from within the marble itself. Microscopic examination fails to discover any chemical transformation which would account for the expansion. Dr. Angus Smith has pointed out that in towns the mortar of walls may be observed to swell up and lose cohesion from a conversion of its lime into the condition of sulphate. I have already mentioned that sulphate does exist within the substance of the marble, but that its quantity so far as I have observed is too small to be taken into account in this question. The expansive power is exerted in such a way as not sensibly to affect the internal structure and composition of the stone, and this I imagine is most probably the work of frost.

The results of my observations among our burial grounds show that, save in exceptionally sheltered situations, slabs of marble exposed to the weather in such a climate and atmosphere as that of Edinburgh are entirely destroyed in less than a century. When this destruction takes place by simple comparatively rapid superficial solution and removal of the stone, the rate of lowering of the surface amounts sometimes to about a third of an inch (or roughly nine millimetres) in a century. Where it is effected by internal displacement, a curvature of two and a half inches with abundant rents, a partial effacement of the inscription and a reduction of the marble to a pulverulent condition may be produced in about forty years, and a total disruption and effacement of the stone within one hundred. It is evident that white marble is here utterly unsuited for out-of-door use, and that its employment for really fine works of art which are meant to stand in the open air in such a climate ought to be strenuously resisted. Of course I am now referring not to the durability of marble generally, but to its behaviour in a large town with a moist climate and plenty of coal smoke.

II. SANDSTONES AND FLAGSTONES.—These, being the common building materials of the country, are of most frequent occurrence as monumental stones. When properly selected, they are remarkably durable. By far the best varieties are those which consist of a nearly pure fine siliceous sand, with little or no iron or lime, and without trace of bedding structure. Some of our sandstones contain 98 per cent. of silica. A good illustration of their power of resisting the weather is supplied by Alexander Henderson's tomb in Greyfriars Churchyard. He died in 1646, and a few years afterwards the present tombstone, in the form of a solid square block of freestone, was erected at his grave. It was ordered to be defaced in 1662 by command of the Scottish Parliament, but after 1688 it was repaired. Certain bullet marks upon the stone are pointed out as those of the soldiery sent to execute the order. Be this as it may, the original chisel marks on the polished surface of the stone are still perfectly distinct, and the incised lettering remains quite sharp. Two hundred years have effected hardly any change upon the stone, save that on the west and south sides, which are those most exposed to wind and rain, the surface is somewhat roughened, and an internal fine parallel jointing begins to show itself.

Three obvious causes of decay in arenaceous rocks may be traced among our monuments. In the first place, the presence of a soluble or easily removable matrix in which the sand grains are embedded. The most common kinds of matrix are clay, carbonates of lime and iron, and the anhydrous and hydrous peroxides of iron. The presence of the iron reveals itself by its yellow, brown, or red colour. So rapid is disintegration from this cause, that the sharply-incised date of a monument

[1] It is a further curious fact that the slab measures half an inch more in breadth across the centre where it has had room to expand than at the top where it has been tightly jammed between the sandstone slabs.

erected in Greyfriars Church to an officer who died only in 1863 is no longer legible. At least $\frac{1}{8}$th of an inch of surface has here been removed from a portion of the slab in sixteen years, or at the rate of about $\frac{3}{4}$ inch in a century.

In the second place, where a sandstone is marked by distinct laminæ of stratification, it is nearly certain to split up along these lines under the action of the weather if the surface of the bedding planes is directly exposed. This is well known to builders, who are quite aware of the importance of "laying a stone on its bed." Examples may be observed in our churchyards, where sandstones of this character have been used for pilasters and ornamental work, and where the stone set on its edge has peeled off in successive layers. In flagstones, which are merely thinly-bedded sandstones, this minuter lamination is fatal to durability. These stones, from the large size in which slabs of them can be obtained and from the ease with which they can be worked, form a tempting material for monumental inscriptions. The melancholy result of trusting to their permanence is strikingly shown by a tombstone at the end of the South Burying Ground in Greyfriars Churchyard. The date inscribed on it is 1841, and the lettering that remains is as sharp as if cut only recently. The stone weathers very little by surface disintegration. It is a laminated flagstone set on edge, and large portions have scaled off, leaving a rough, raw surface where the inscription once ran. In this instance a thickness of about $\frac{1}{3}$ inch has been removed in forty years.

In the third place, where a sandstone contains concretionary masses of different composition or texture from the main portion of the stone, these are apt to weather at a different rate. Sometimes they resist destruction better than the surrounding sandstone, so as to be left as prominent excrescences. More commonly they present less resistance, and are therefore hollowed out into irregular and often exceedingly fantastic shapes. Examples of this kind of weathering abound in our neighbourhood. Perhaps the most curious to which a date can be assigned are to be found in the two sandstone pillars which until recently flanked the tomb of Principal Carstares in Greyfriars Churchyard. They were erected some time after the year 1715. Each of them is formed of a single block of stone about 8 feet long. Exposure to the air for about 150 years has allowed the original differences of texture or composition to make their influence apparent. Each is hollowed out for almost its entire length on the exposed side into a trough 4 to 6 inches deep and 6 to 8 inches broad. As they lean against the wall beneath the new pillars which have supplanted them, they suggest some rude form of canoe rather than portions of a sepulchral monument.

Where concretions are of a pyritous kind, their decomposition gives rise to sulphuric acid, some of which combines with the iron and gives rise to dark stains upon the corroded surface of the stone. Some of the sandstones of this district, full of such impurities, ought never to be employed for architectural purposes. Every block of stone in which they occur should be unhesitatingly condemned. Want of attention to this obvious rule has led to the unsightly disfigurement of public buildings.

III. GRANITES.—In Prof. Pfaff's experiments, to which I have already referred, he employed plates of syenite and granite, both rough and polished. He found that they had all lost slightly in weight at the end of a year. The annual rate of loss was estimated by him as equal to 0·0076 mm. from the unpolished and 0·0085 from the polished granite. That a polished surface of granite should weather more rapidly than a rough one is perhaps hardly what might have been expected. The same observer remarks that though the polished surface of syenite was still bright at the end of not more than three years, it was less so than at first, and in particular that some figures indicating the date which he had written on it with a diamond had become entirely effaced. Granite has been employed for too short a time as a monumental stone in our cemeteries to afford any ready means of measuring even approximately its rate of weathering. Traces of decay in some of its felspar crystals may be detected, yet in no case that I have seen is the decay of a polished granite surface sensibly apparent after exposure for fifteen or twenty years. That the polish will disappear, and the surface will gradually roughen as the individual component crystals are more or less easily attacked by the weather, is of course sufficiently evident. Even the most durable granite will probably be far surpassed in permanence by the best of our siliceous sandstones. But as yet the data do not exist for making any satisfactory comparison between them.

GERHARD JOHANNES MULDER

IN the death of Prof. G. J. Mulder, to which we briefly alluded in our last number, Holland has been called upon to mourn the loss of her leading chemist. Gerhard Johannes Mulder was born at Utrecht, December 27, 1802. His studies were completed at the university of his native city, and embraced especially mathematics, the natural sciences, and medicine. In 1825 he established himself as physician at Amsterdam. His inclination towards a more purely scientific career caused him however in the year following to accept a position as teacher of physics at Rotterdam under the auspices of the Batavian Society. This proved but the stepping-stone to the Professorship of Botany and Chemistry at the Rotterdam Medical School, to which he was appointed in 1827. In 1841 he accepted a call to the Chair of Chemistry at Utrecht, and returned to the place of his birth, to add to its fame by making it the scene of a long-continued series of valuable chemical researches.

Mulder's tastes lay almost entirely in the department of organic chemistry, and more especially in those branches connected with the phenomena of vegetable and animal life. In mineral chemistry his researches were confined to careful studies on the chemical composition of white lead and red lead (1839)—two of the important technical products of Holland—and to the establishment of the atomic weight of tin (1849) by means of numerous analyses. He also modified or perfected a number of analytical methods, such as those for the determination of silver, phosphorus, carbonic acid, &c., and contributed a large variety of analytical data on various technical and scientific compounds. In 1864 he made an elaborate investigation on the phenomena of solution of salts in water, establishing several of the now generally accepted laws with regard to the solubility of mixtures of salts, among others the interesting fact that in saturated solutions of mixtures the relations between the respective quantities of the salts is expressed in multipla of their molecular weights. The varied experimental data resulting from his own researches were grouped, together with the contributions of other chemists on this subject, in the form of a monograph of over 300 pages, which forms the most important work extant on solubility.

In physiological chemistry Mulder has conducted a large variety of investigations. The most important are those connected with the study of the albuminoids, which were commenced in 1838 and extended over a period of twenty years. In the course of these investigations he exposed albumin, fibrine, caseïne, &c., to the action of a variety of chemical agents, obtaining the products of oxidation, chlorination, nitrification, &c. At an early date he obtained, by the action of alkaline solutions on the albuminoids, the so-called *protein*, which he regarded as the primary albuminoid matter, the various members of the group consisting of this radical in union with small quantities of sulphur, phosphorus, and oxygen. This